Army Icing Remote Sensing

Chuck Ryerson
Geoff Koenig

ERDC-CRREL

ERDC
Engineer Research and Development Center

Outline

1. Program direction
2. RADTRAN
3. WaveBand
4. MWISP report
4. RS marketing
   a. Army Aviation S&T review
   b. DCD Aviation and AMCOM
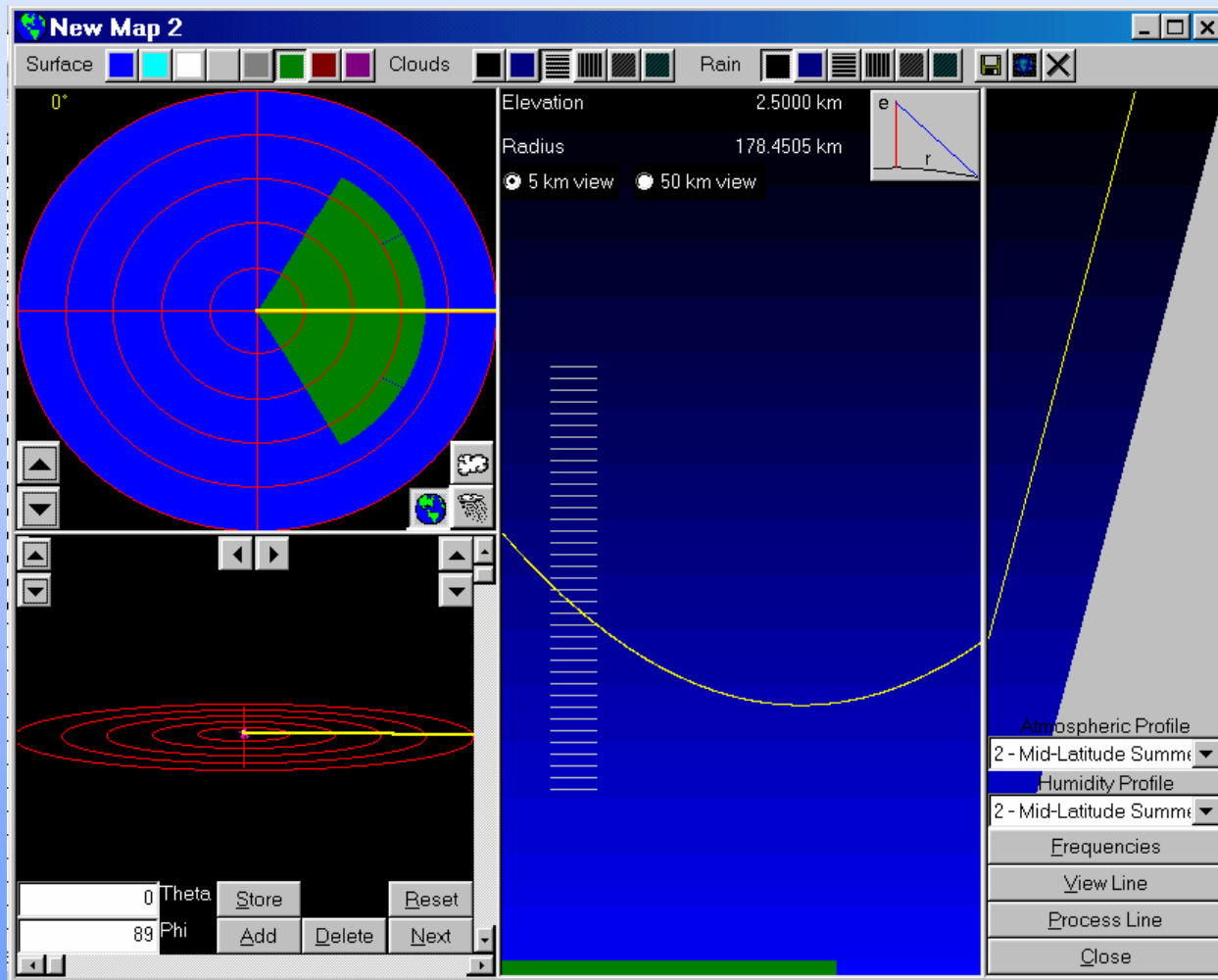5. AIRS II plans

RS Program Direction

Emphasis on Inflight remote sensing

for rotorcraft, UAVs, AMT, all DoD

(algorithm & hardware development, T&E, operational

scenarios, emphasis on passive systems)

Characterize meteorological conditions

(Remote sensing and aircraft performance)

Recent Enhancements to RADTRAN

RADTRAN

➢ **Plane parallel model that calculates the frequency dependent brightness temperature, transmittance, and attenuation for specified environmental conditions.**

➢ **Frequency range: 1 to 300 GHz, tested to 1000 GHz**

➢ **RADTRAN physics:**

✓ **Atmospheres: Tropical, mid-latitude summer, mid-latitude winter, sub-arctic summer, sub-arctic winter, U.S. standard, and user defined**

✓ **Atmosphere frequency dependent absorption and emission: water vapor, oxygen, ozone, carbon monoxide, and nitrous oxide**

✓ **Precipitation frequency dependent scattering and multiple scattering: For clouds and fog the drop distribution is defined using a modified gamma function and Rayleigh scattering. For rain Mie calculation based on the Marshall-Palmer or Best distribution are used to calculate the scattering**

RADTRAN CONT'D

➢**RADTRAN physics:**

✓ **Cloud types:** no cloud, stratus/strato cumulus, typical summer cumulus rain cloud, altostratus, stratus cumulus, and nimbostratus

Rain intensities: no rain, drizzle 2mm/hr, light rain 5mm/hr, steady rain 12.5mm/hr, summer cumulus rain 15mm/hr, and heavy rain 20mm/hr. Handles both water and ice precipitation absorption, extinction and scattering; temperature and frequency dependent refractive index; and Marshall-Palmer and Best drop distribution

✓ **Frequency dependent surface polarized emission and scattering:** calm ocean, rough foam sea surface, multi-year and first-year sea ice, dry snowpack, wet snowpack, vegetation, wet soil, and random medium (provide average dielectric constant and variance). User defined horizontal and vertical emissivities.
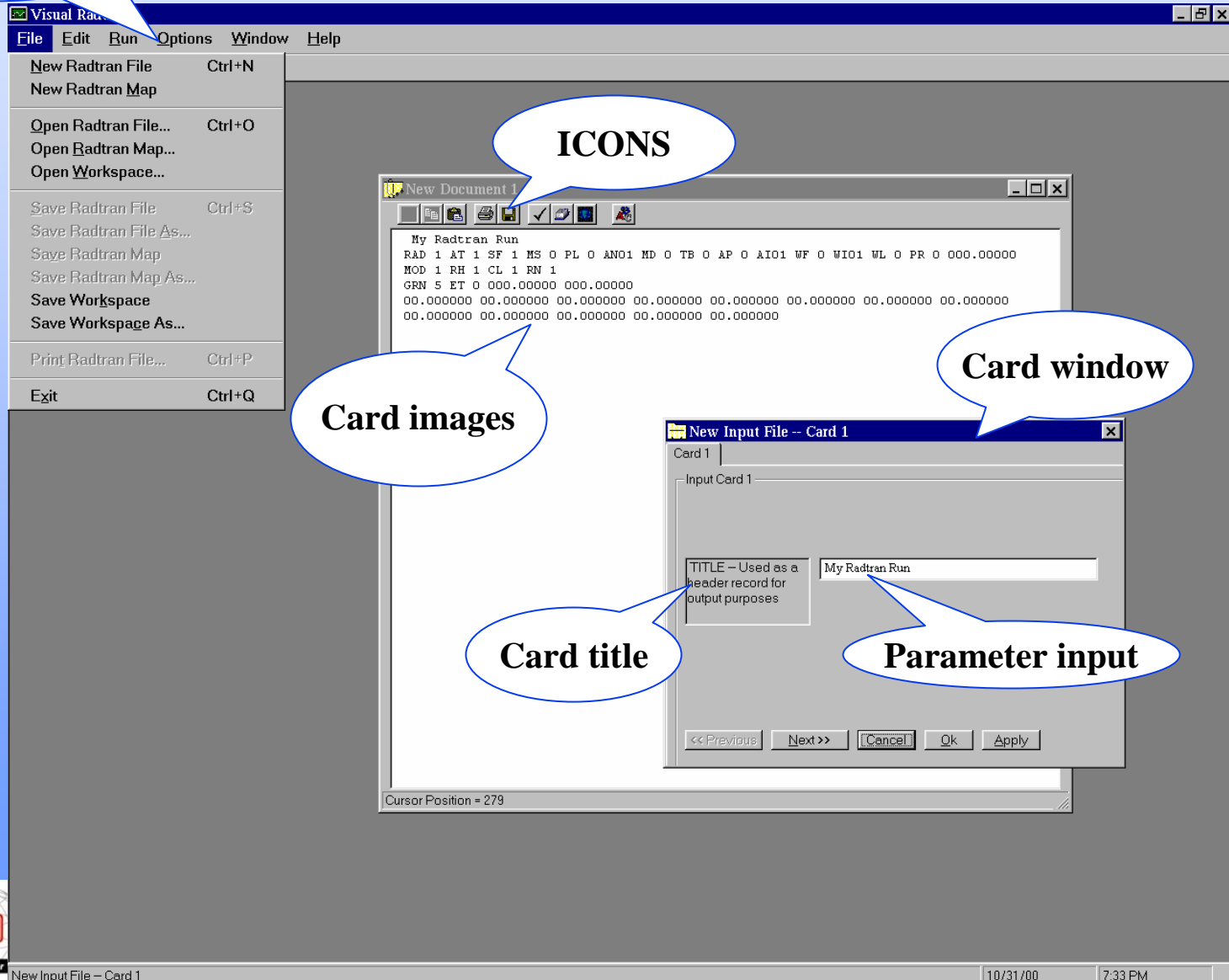
✓**Multiple Scattering Calculations:**
Scalar calculation - no surface and nadir path
Vector calculation - non nadir path and physical surface

ERDC
Engineer Research and Development Center

RADTRAN GUI-Run Mode

RADTRAN GUI-Run Mode

Default models

Auxiliary input

RADTRAN RUN MODE

Mid Latitude Summer

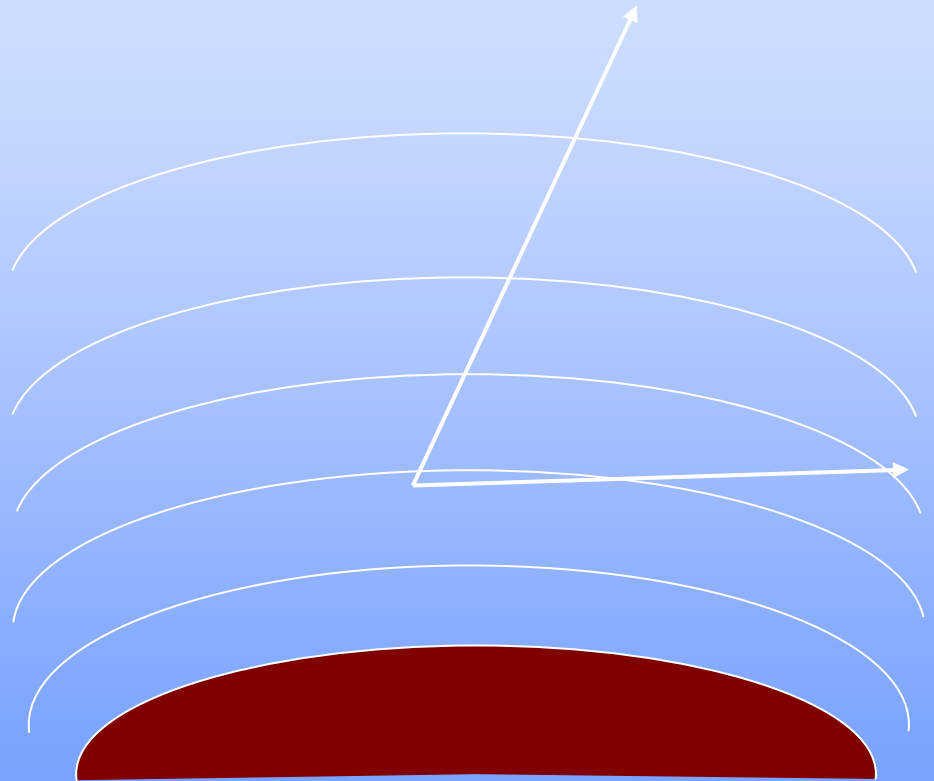Precipitable Water =5.03 cm
Total LWC = 0.428 g/cm^2

LWC

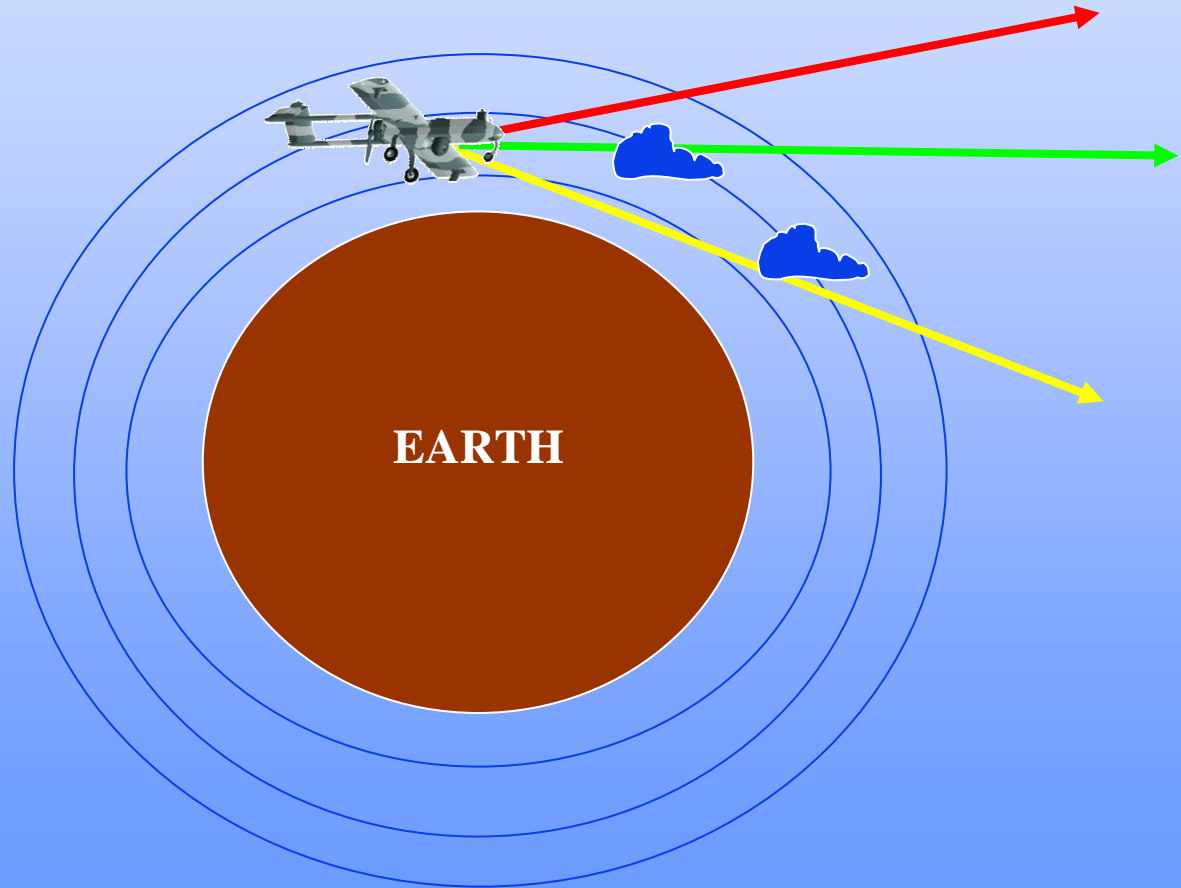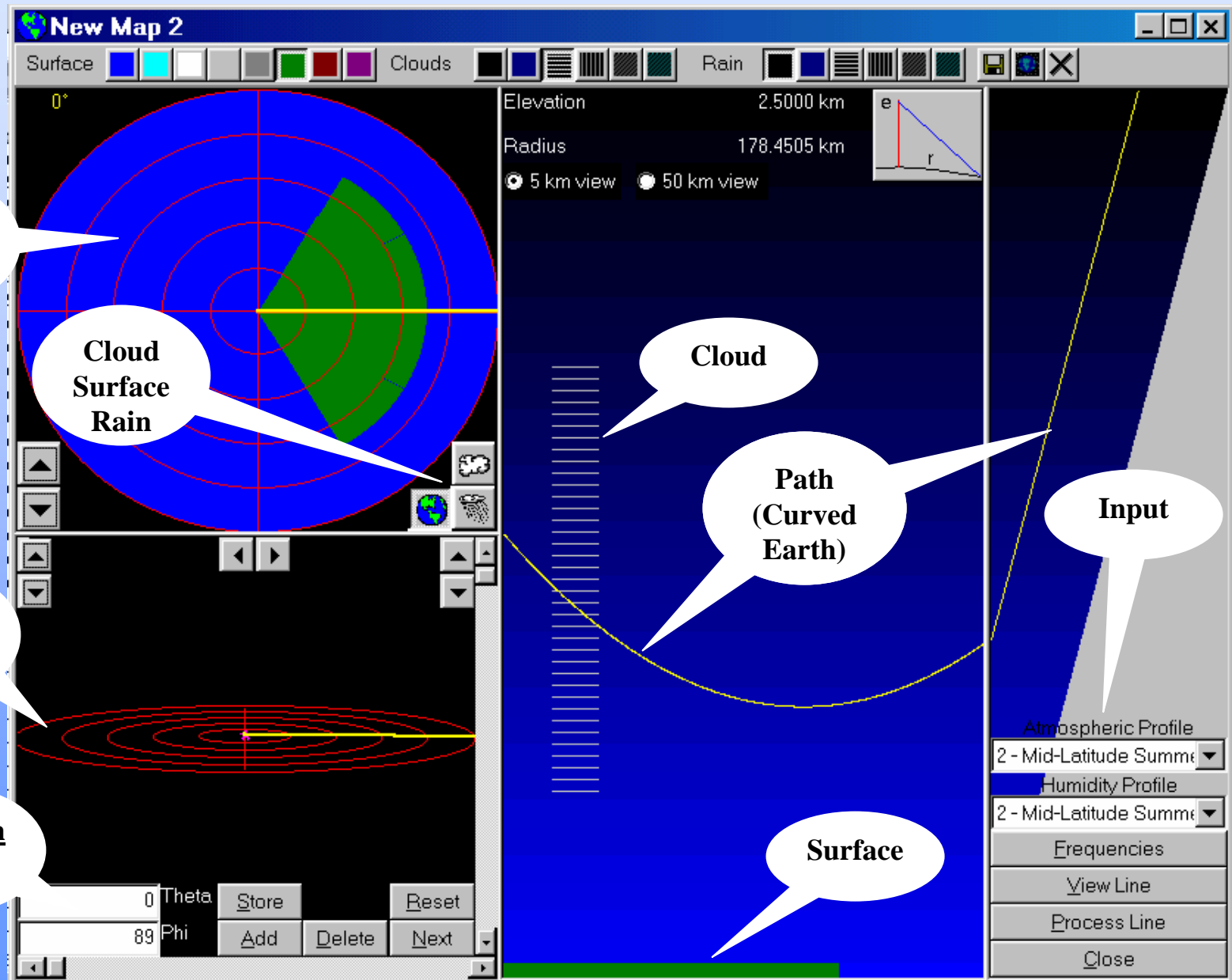Rain Rate
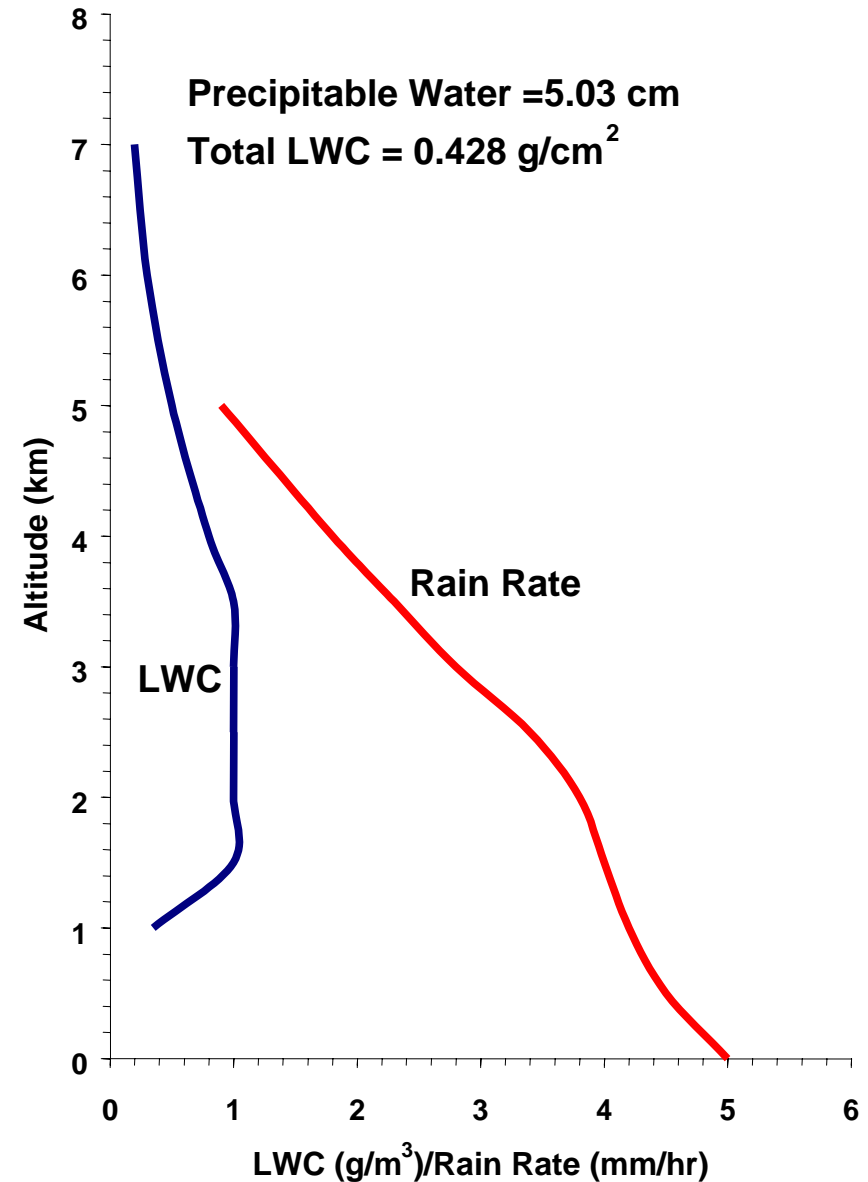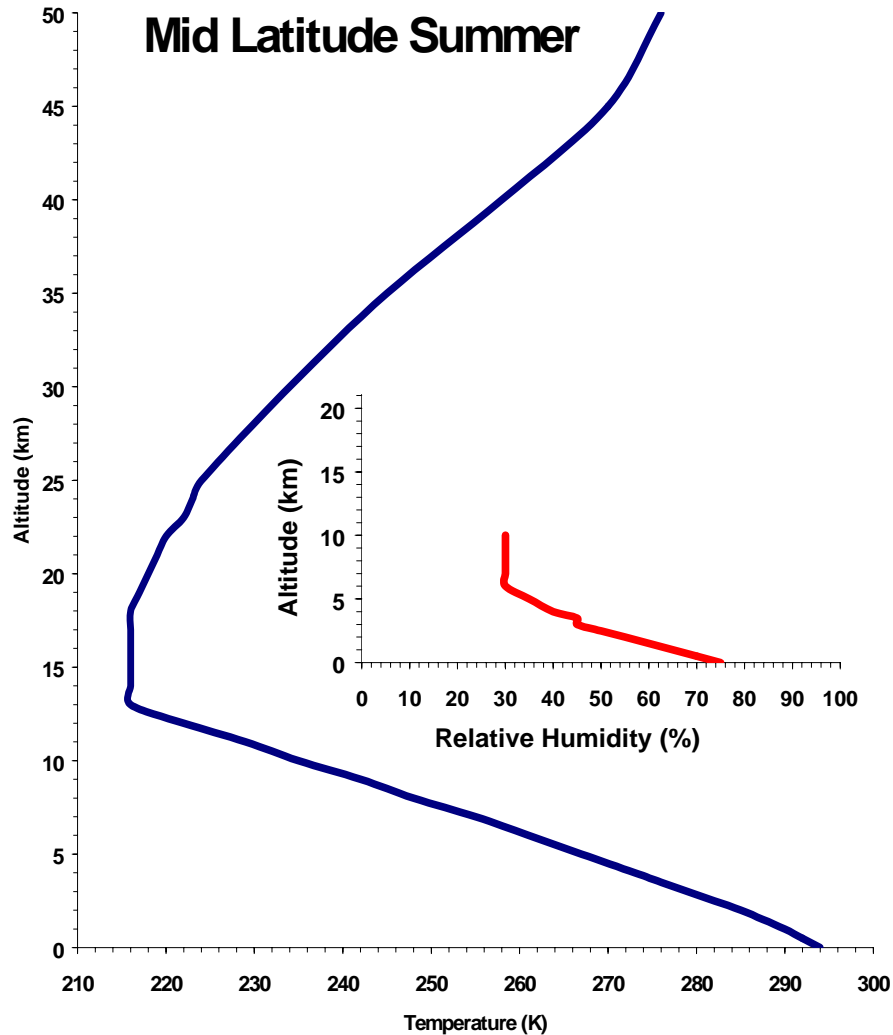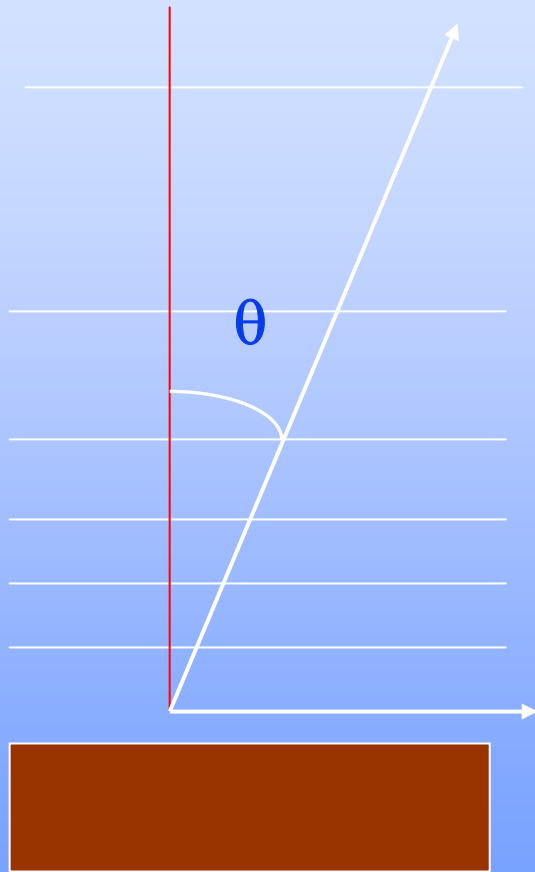
RADTRAN Map Mode

Run Mode

Map Mode

Onion Skin Atmosphere

– now correctly handles the far boundary condition

RADTRAN GUI-Map Mode

RADTRAN Map Mode

Slant Path Atmospheric Profile
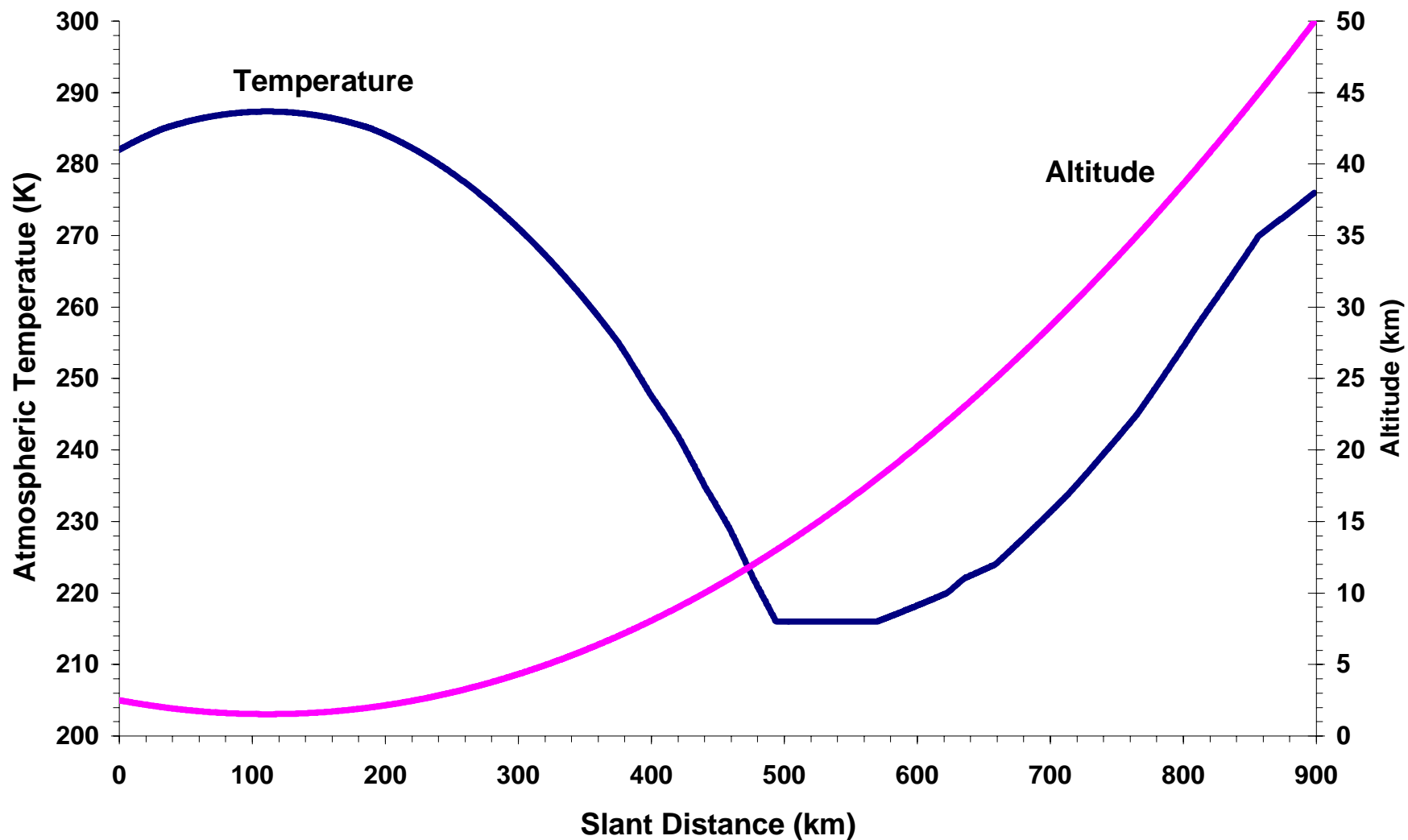
RADTRAN Map Mode

Slant Path Transmission and Attenuation 89GHz
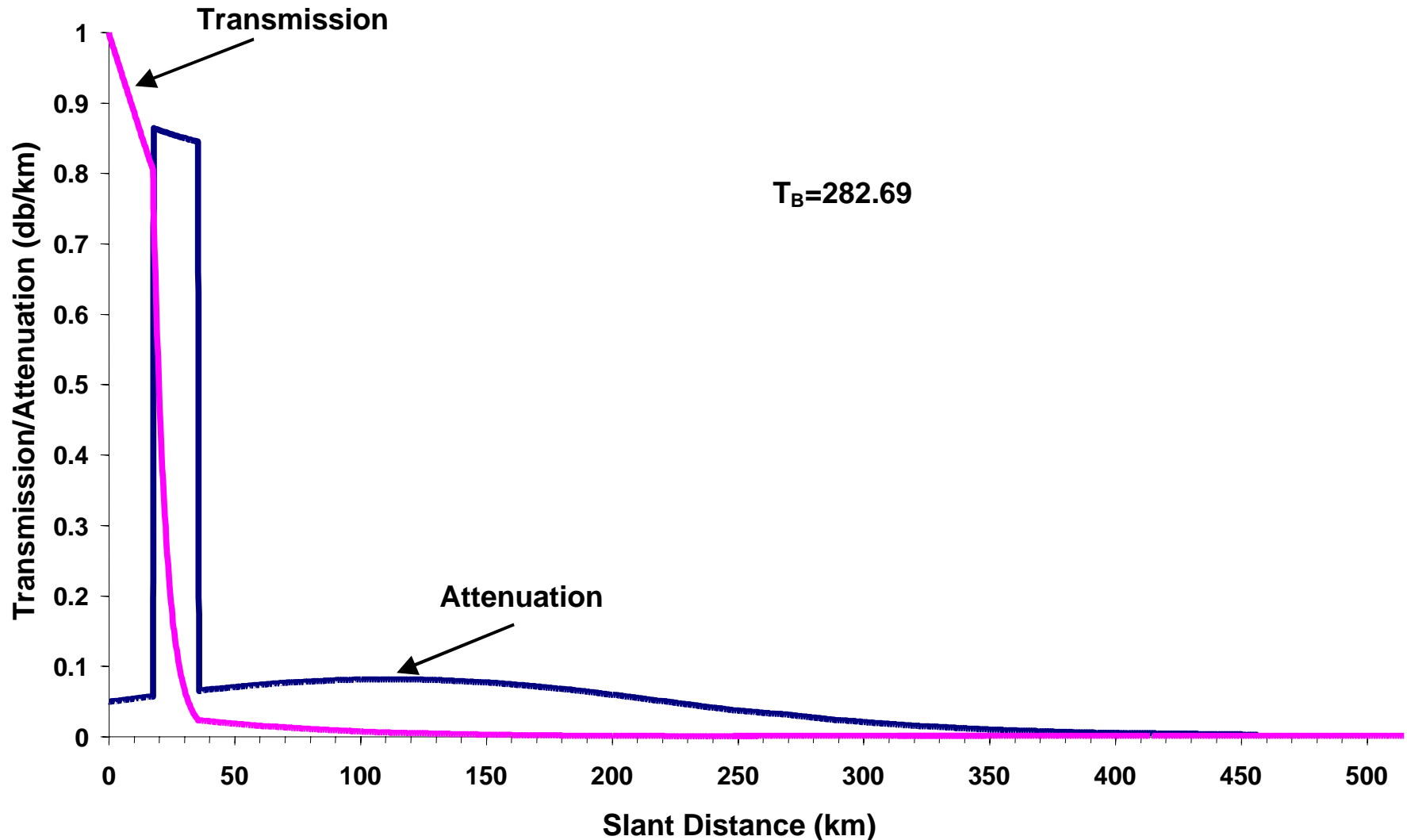
Microwave Radiometry RADTRAN
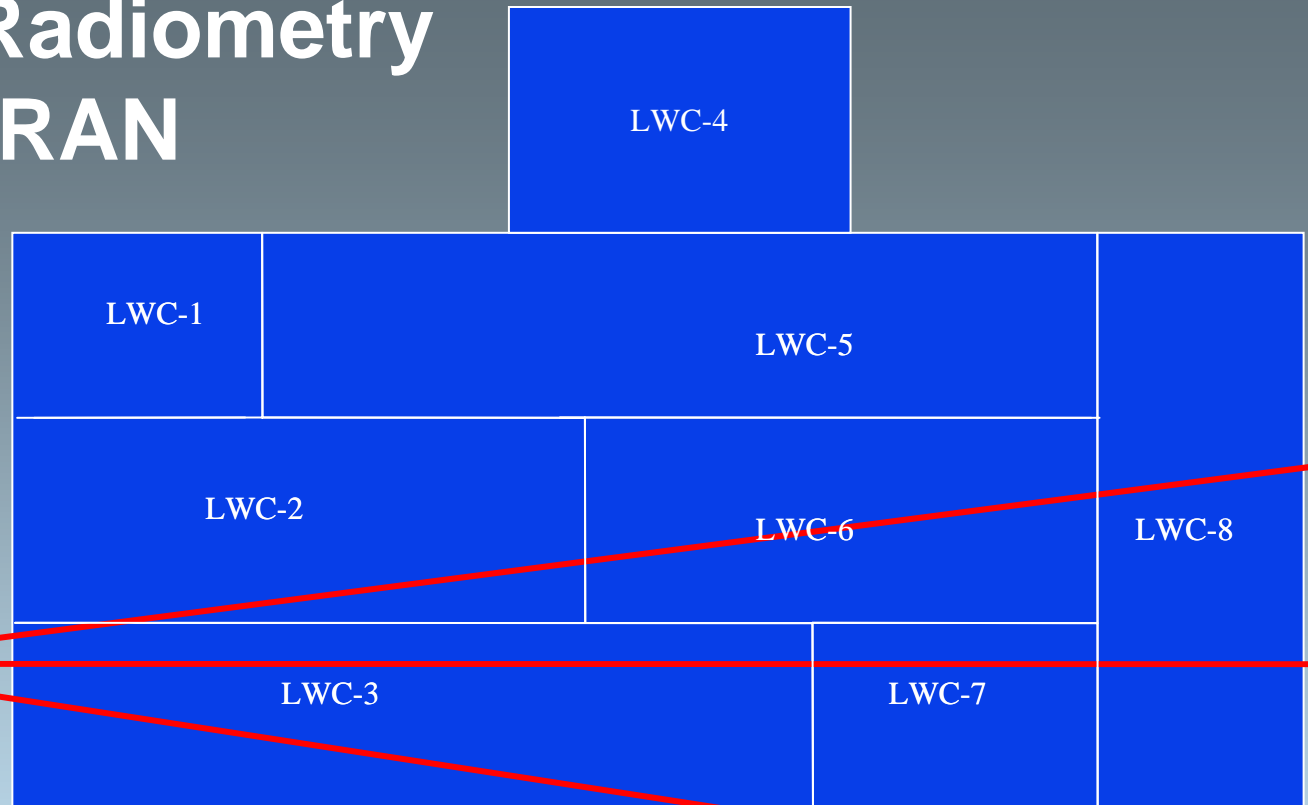
Multi-Frequency, Multi-view Radiometer for Icing Potential Detection

A — 0.5 g/m³ | 1.5 g/m³

B — 0.5 g/m³ | 1.5 g/m³

C — 0.5 g/m³ | 1.5 g/m³

D — 0.5 g/m³ | 1.5 g/m³

89 GHz →
37 GHz →

Brightness Temperature (K)

A B C D

89 GHz TB

37 GHz TB

89-37 GHz TB

Cloud 1
0.5 g/cm³

Cloud 2
1.5 g/cm³

Aircraft Position (km)
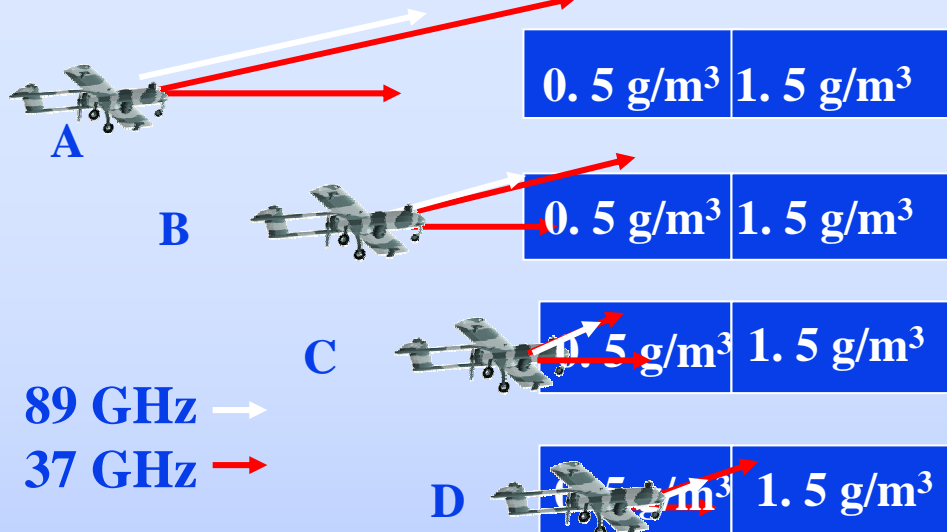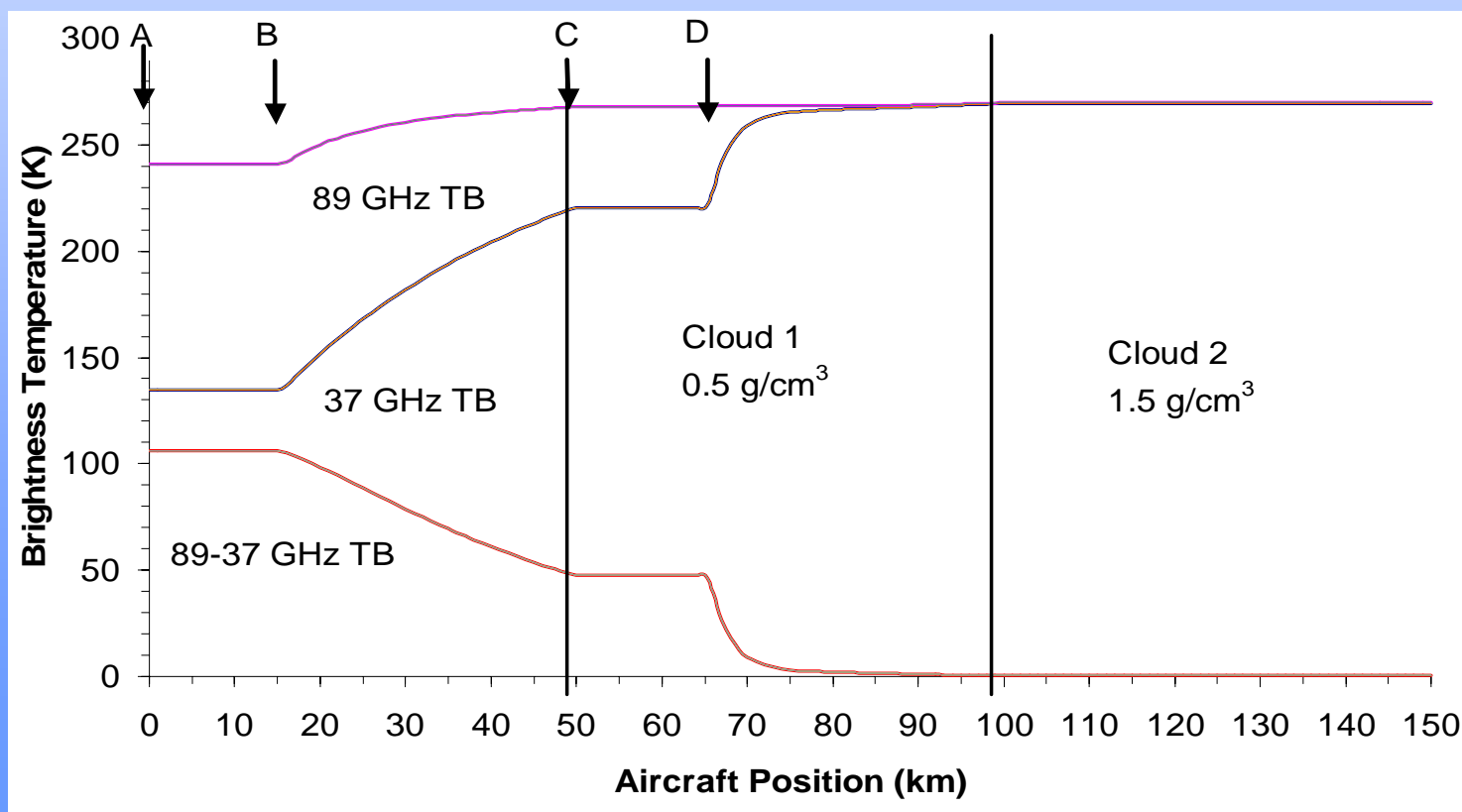
RADTRAN Summary & Future Work

➢Software & documentation completed by end of FY 03.

➢Recent NASA funding to look at implementing ice and mixed
Phase clouds in RADTRAN

➢ Propose use of RADTRAN to evaluate capabilities of WaveBand radiometer *Passive MMW Polarimetric Target and Natural Background Detection*

WaveBand MMW Icing Polarimeter

- **Phase II funded**
- **Kickoff 16 October at CRREL**
- **Determine deliverables and radiometer features**
- **Letters of support from NASA-GRC and FAA-WJHTC**
- **Received option funding**
- **Contract to be let in October – expected completion is October 2005**

Polarimetric Scanning Radiometer (PSR)

The polarization effects has been used for atmospheric studies, including icing conditions in clouds

For routine use a compact and cost-effective solution is required
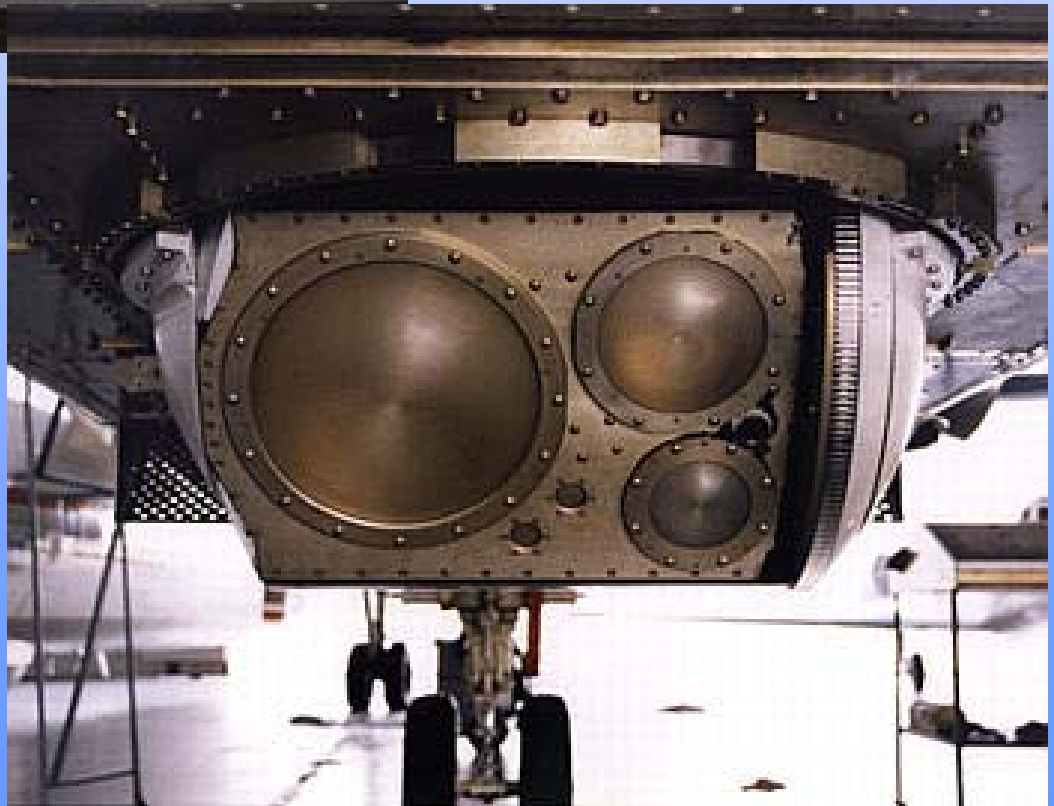
Remote Detection of Inflight Icing Conditions

Proposed Phase II SBIR
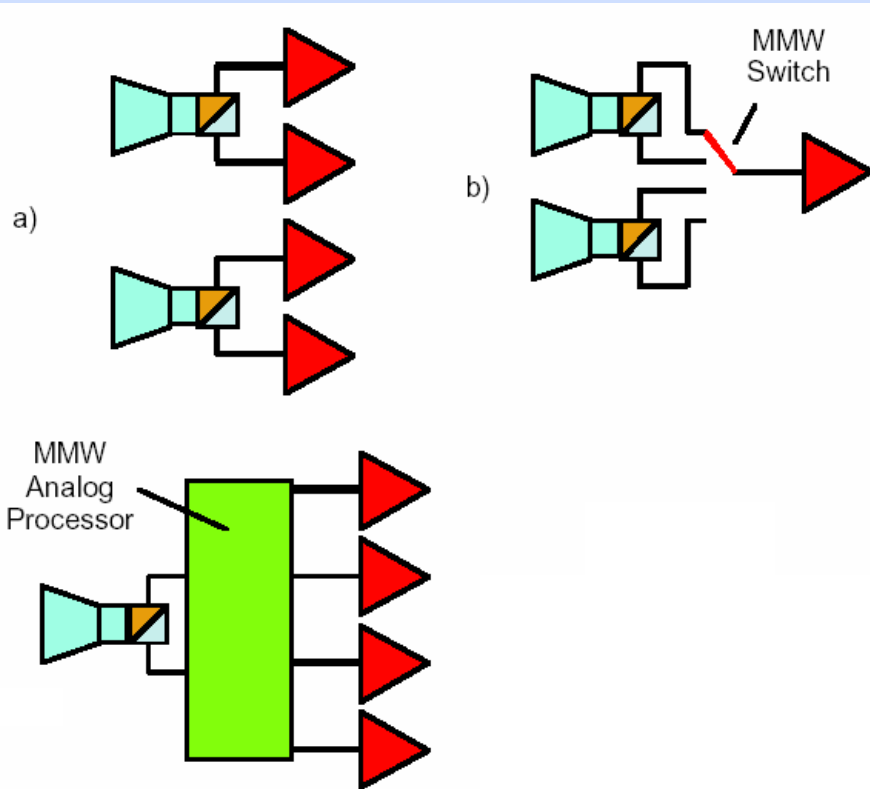
- **Small size, weight, power and cost**
- **Revolutionary design**
- **Fit on UAV or helicopter**
- **Radar or radiometer configuration**
- **Four Stokes parameters**
- **Detect icing conditions**
- **Improved target detection**
- **Synthetic vision for landing through dust, snow, or fog**
- **Detection of runways through snow cover**
- **Detection of wires**
- **Determine state of the ground**
- **Image weapons through clothing**

PHASE II DESIGN

INNOVATIONS:

· **Dynamical operation**

ADVANTAGES
(in comparison with traditional approaches):

Direct measurements of three independent Stokes parameters (Q,U, and V)
Only one measurement channel
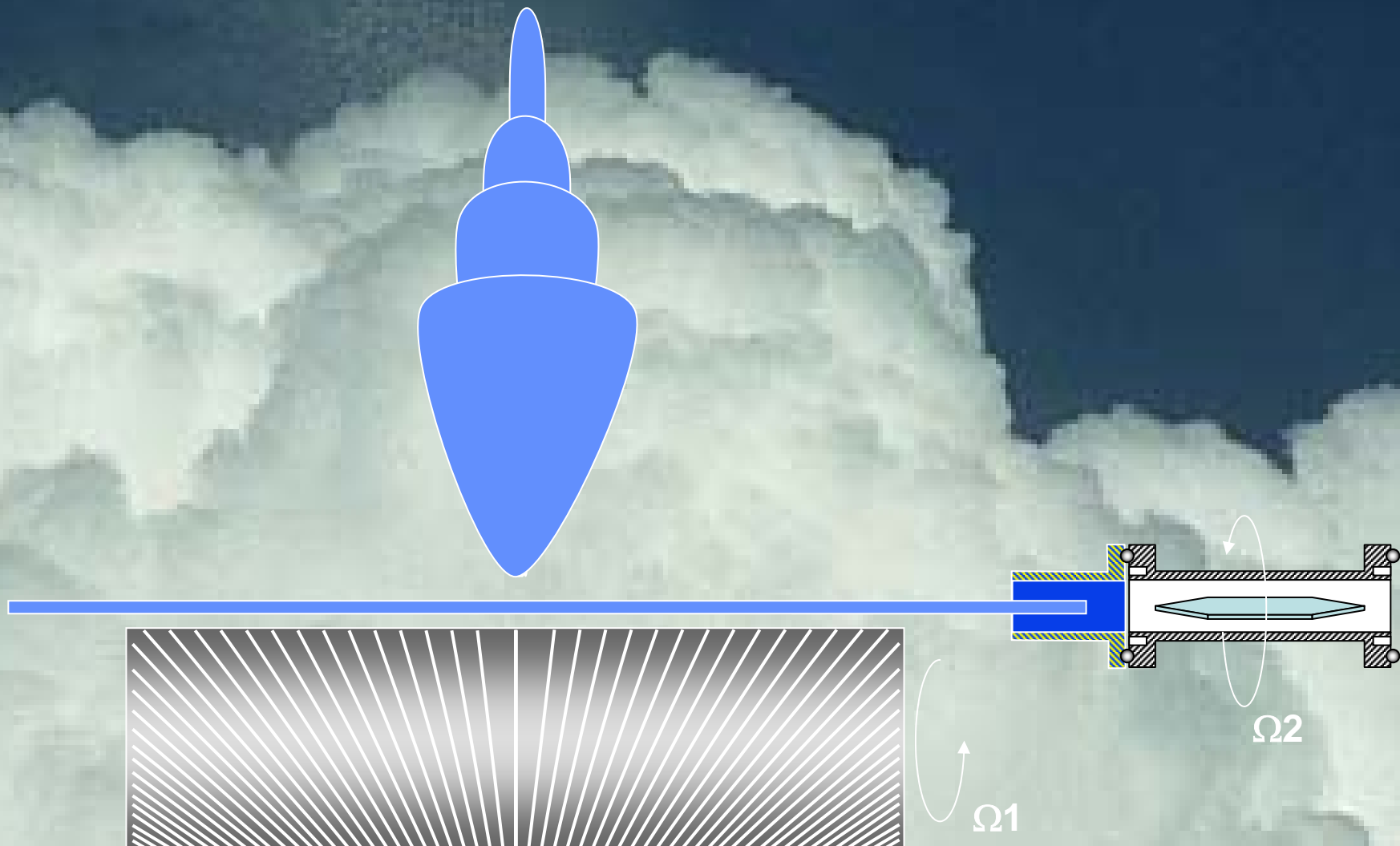**AC operation**
No switches
Low flicker noise
No drift
Low measurement errors
Compactness
Lightweight
Cost effectiveness

Integration of the polarimetric radiometer with WaveBand's zooming antenna

$\Omega 2$

$\Omega 1$

CRREL MWISP Report

- **Completed draft**
- **Reviewed by ERDC Editing and co-authors (Koenig and Scott)**
- **Must integrate Editing and co-author comments**
- **Includes:**
    - **Instrumentation**
    - **Weather summary**
    - **Probe calibration**
    - **Data processing**
    - **Products**
    - **LWC comparison between instruments**
    - **5 CDs with 5-min summaries**
    - **Plymouth State Korolev particle type identification**

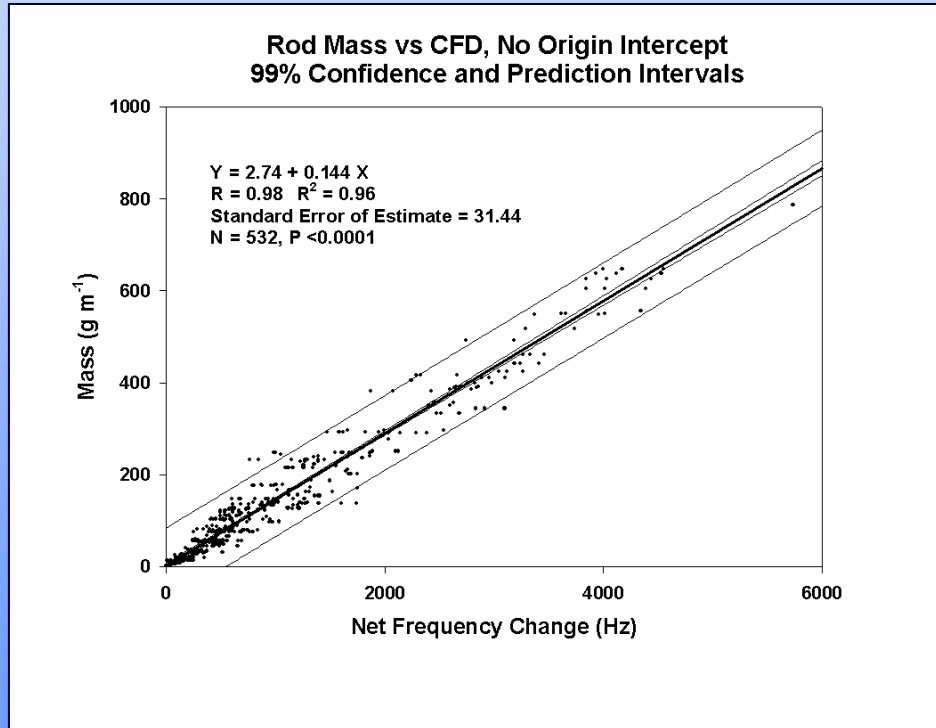- **Expect reviewable draft by late October**

DoD Marketing

- **Army Aviation S&T Review 2003**
  - **Considerable interest in WaveBand radiometer – icing and landing zone obstacles**
- **Visit to Ft. Rucker and AMCOM (Huntsville)**
  - **Interest in icing and radiometer at ATTC**
  - **PM Commanche interested in radiometer for icing**
  - **PM Chinook interested in radiometer for landing**

AIRS-II

- **Working with NASA-GRC and ground station in IOP #1 at Mirabel**
- **Will provide ASOS ice detector and PC for ground ice monitoring**

Rod Mass vs CFD, No Origin Intercept
99% Confidence and Prediction Intervals

$Y = 2.74 + 0.144\ X$
$R = 0.98\quad R^2 = 0.96$
Standard Error of Estimate = 31.44
$N = 532,\ P < 0.0001$

Mass (g m^{-1}) vs Net Frequency Change (Hz)

Summary

- **WaveBand funding is promising**

- **Must make more progress on radiometer modeling**

- **Continuing Cober and clustering work**

- **Wish to continue to participate in remote sensing of icing and cloud physics work**

- **MWISP nearly ready for review**